Desert Pupfish (*Cyprinodon macularius*)


Photo courtesy of Sharon Keeney, CDFW

Legal Status

State: Endangered
Federal: Endangered
Critical Habitat: 51 FR 10842–10851
Recovery Planning: Desert Pupfish Recovery Plan (USFWS 1993)

Taxonomy

The desert pupfish complex was historically comprised of two subspecies, the nominal desert pupfish (*Cyprinodon macularius macularius*) and the Quitobaquito pupfish (*Cyprinodon macularius eremus*), and an undescribed species, the Monkey Spring pupfish (*Cyprinodon* sp.) (USFWS 1993). The subspecies are now recognized as three separate species (USWFS 2010): the desert pupfish (*C. macularius*), the Sonoyta (Quitobaquito) pupfish (*C. eremus*) (Echelle et al. 2000), and the undescribed Monkey Springs pupfish, which has since been described and renamed the Santa Cruz pupfish (*C. arcuatus*). Recent work (Echelle et al. 2007; Koike et al. 2008) and a summary by the U.S. Fish and Wildlife Service (USFWS 2010) provide the evidence that *C. macularius* and *C. eremus* are separate species. The Sonoyta pupfish persists in only two populations: one near the U.S.–Mexico border at Quitobaquito Springs in Organ Pipe Cactus National Monument in Arizona, and the other at Rio Sonoyta in Sonora, Mexico (USFWS 2010). The Santa Cruz pupfish occurred in the upper Santa Cruz River basin in southern Arizona and Northern Sonora, Mexico. It is now extinct due to habitat alteration and introduced fishes (Minckley et al. 2002). All other populations are referred to *C. macularius*. Descriptions of the species' physical characteristics can be found in USFWS (1993, 2010).

Distribution

General

The desert pupfish occurs in desert springs, marshes, and tributary streams of the lower Gila and Colorado River drainages in Arizona, California, and Mexico. Natural populations of desert pupfish also occur in the Salton Sea and associated irrigation drains and shoreline pools. It also formerly occurred in the slow-moving reaches of some large rivers, including the Colorado, Gila, San Pedro, and Santa Cruz.

Distribution and Occurrences within the Plan Area

Historical

Historically, desert pupfish occurred in the lower Colorado River in Arizona and California, from about Needles downstream to the Gulf of Mexico and onto its delta in Sonora and Baja (CVAG 2007). In California, pupfish inhabited springs, seeps, and slow-moving streams in the Salton Sink basin, and backwaters and sloughs along the Colorado River. Desert pupfish also occurred in the Gila River Basin in Arizona and Sonora, including the Gila, Santa Cruz, San Pedro, and Salt Rivers; the Rio Sonoyta of Arizona and Sonora; Puerto Penasco, Sonora; and the Laguna Salada Basin of Baja California.

Recent

Because *C. eremus* occurs only in southern Arizona and Mexico (USFWS 2010) and *C. arcuatus* is now extinct, their distribution information is not discussed further; *C. macularius* is described within the Plan Area (see Figure SP-F01). USFWS (2010) describes that currently five natural populations persist in California, restricted to two streams tributary to, and many shoreline pools and irrigation drains of, the Salton Sea: San Felipe Creek/San Sebastian Marsh, Salt Creek (within the Dos Palmas Conservation Area of the Coachella Valley Multiple Species Habitat Conservation Plan [MSHCP; CVAG 2007]), Salton Sea, irrigation drains of the Salton Sea, and a wash near Hot Mineral Spa (a natural population added since the 1993 recovery plan). The desert pupfish population in Salt Creek is stable to increasing, and currently has few non-native species (Keeney 2010a, cited in USFWS 2010). San Felipe Creek also has a stable to increasing population. California Department of Fish and Wildlife (CDFW) surveys have found a persistent population of western mosquitofish (*Gambusia affinis*) in San Felipe Creek in recent years. In addition, there are a number of refuge or captive populations of desert pupfish in California at a variety of sites (USFWS 2010): Anza-Borrego State Park; Oasis Springs Ecological Reserve; Salton Sea State Recreation Area; Dos Palmas Reserve; Living Desert Museum; University of California, Riverside; and Borrego Springs High School. The Coachella Valley MSHCP (CVAG 2007) also describes a refuge population in the larger pools around the Thousand Palms oasis area where restoration is in progress. There are no pupfish currently present here, but there are plans to restock this site when restoration has been completed.

Natural History

Habitat Requirements

Found in water of desert springs, small streams, and marshes below 1,515 meters (5,000 feet) elevation (USFWS 1993), this species tolerates high salinities, high water temperatures, and low dissolved-oxygen concentrations. In the mid-2000s CDFW found desert pupfish in the Salton Sea at depths of 7 to 8 feet while conducting fish monitoring surveys. Pupfish typically prefer clear water, with either rooted or unattached aquatic plants, restricted surface flow, and sand–silt substrates (Black 1980; USFWS 1993). Pupfish use shallow water habitats extensively, often occupying such habitat at temperatures that are above the thermal optimum for invasive fishes. Pupfish do well if these habitats have little vegetation apart from mats of benthic algae over a fine-grained mineral or detrital substrate; they also utilize areas with aquatic or emergent vascular vegetation (ICF 2009). Desert pupfish in general are noted for their tolerance of environmental stress; they can tolerate dissolved-oxygen concentrations as low as 0.13 parts per million (Helfman et al. 1997). Their temperature tolerance ranges from a low of 4.4°C (Schoenherr 1990) to a high of 42.4°C (Carveth et al. 2006). Their salinity tolerance ranges from 0 to 70 parts per thousand for eggs and adults (Barlow 1958; Schoenherr 1988) and up to 90 parts per thousand for larvae (Schoenherr 1988). Martin and Saiki (2005) found that desert pupfish abundance was higher when vegetative cover, pH, and salinity were high and when sediment factor and dissolved oxygen were low. They hypothesize that water quality extremes (especially high pH and salinity, and low dissolved oxygen) limit the occurrence of nonnative fishes.

Table 1. Habitat Associations for Desert Pupfish

Land Cover Type	Land Cover Use	Habitat Designation	Habitat Parameters	Supporting Information
Water of desert springs, small streams, and marshes	Breeding/ foraging	Primary habitat	Clear water, with either rooted or unattached aquatic plants, restricted surface flow, and sand–silt substrates	Direct observational studies

Sources: Black 1980; USFWS 1993; Martin and Saiki 2005.

Foraging Requirements

Pupfish are opportunistic omnivores, thriving on a diet of algae, aquatic plants, detritus, and small invertebrates (Sutton 1999, citing Crear and Haydock 1971 and Naiman 1979). Adult foods include ostracods, copepods, and other crustaceans and insects; pile worms; mollusks; and bits of aquatic macrophytes torn from available tissues (USFWS 1993). Legner et al. (1975) found that desert pupfish were more effective than mosquitofish at controlling mosquito populations. Pupfish have also been known to eat their own eggs and young on occasion. Detritus or algae are often predominant in their diets (USFWS 1993). Pit digging, the active excavation of soft bottoms in search of food, is a pupfish behavior described by Minckley and Arnold (1969); these pits are defended when occupied. Foraging is typically a daytime activity, and fish may move in response to daily warming from shallower water during morning to feed in deeper places later in the day (USFWS 1993).

Reproduction

Desert pupfish may become sexually mature as early as 6 weeks of age at 1.5 centimeters in length under conditions of abundant food and suitable temperature. Desert pupfish typically live for a year, but may live as long as 2 to 3 years. Although they may breed during their first summer, most do not breed until their second summer, when their length may have reached a maximum of 7.5 centimeters (Moyle 2002). In favorable conditions a pair of pupfish can produce 800 eggs in a season (ICF 2009). Eggs appear to be randomly deposited within the male territory. Although males actively patrol and defend individual territories, there is no directed parental care (USFWS 1993).

Table 2. Key Seasonal Periods for Desert Pupfish

	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Breeding			X	X	X	X	X	X	X			

Source: USFWS 1993.

Spatial Behavior

McMahon and Tash (1988) found that when desert pupfish occupied open pools, 84% of the total number produced emigrated. They found that when pupfish were prevented from emigrating, pupfish exhibited symptoms of overpopulation. Characteristics of overpopulation were not apparent in pupfish occupying open pools. Seasonal temperatures influenced the timing and magnitude of emigration. In summary, pupfish may regulate their populations via emigration.

Many of the locations where they are currently found are isolated from other populations. However, complete isolation mainly has been an issue in artificial populations, although even in these populations "complete isolation" no longer occurs given CDFW's recent inoculation of refuges with wild fish. Most natural populations have some connection to other populations occasionally (e.g., via flash flood), although these opportunities for mixing are brief and infrequent. This may become more of an issue given the uncertainty of the Salton Sea.

Desert pupfish congregate in the summer where adult females swim in loose schools and leave the school when attracted by a territorial male to spawn. Pupfish movement between the Salton Sea and nearby drains has been observed (Sutton 1999). Sutton (2002) describes desert pupfish summer movement between a drain (although not connected directly to the Salton Sea) and a shoreline pool, as well as movement of approximately 0.5 kilometer (0.3 mile) from Salt Creek to a downstream shoreline pool (although not connected to the Salton Sea). Sutton (2002) hypothesizes that movements from Salt Creek to the shoreline pool were due to water level drops. The technique used by Sutton (2002) for tracking desert pupfish holds promise for further desert pupfish movement studies.

Table 3. Spatial Behavior by Desert Pupfish

Type	Distance/Area	Location of Study	Citation
Breeding territory	Normally defends 1 to 2 square meters but as large as 5 to 6 square meters	Not disclosed	Moyle 1976

Ecological Relationships

The desert pupfish were once found in varying water bodies from cienegas and springs to shallow streams and margins of larger bodies of water where they preferred shallow, slower-moving water with soft substrates and clear water (USFWS 1993). Over the last century, land use activities such as groundwater pumping, dewatering, water diversion, and drain maintenance have altered the water levels, resulting in habitat loss for desert pupfish. Channel erosion can increase the sediment in the water, reducing its suitability for the pupfish; water impoundment creates deeper ponds that increase occupation by non-native aquatic species; and grazing practices reduce vegetative cover, increase sedimentation, and trample habitat (USFWS 1993). Off-road vehicle use can be problematic in some areas, and currently is more of an issue than is grazing.

Currently, the major threat to the species is the presence of exotic aquatic species, particularly tilapia (*Tilapia* spp.), sailfin molly (*Poecilia latipinna*), western mosquitofish, several snail species, and crayfish (*Procambarus clarkii*). These and other introduced fish species primarily affect pupfish populations through predation, competition, and behavioral interference (CVAG 2007). Introduced fishes (and other aquatic organisms) can affect pupfish populations via other means as well, such as disease and habitat displacement. Additionally, in a few areas, such as San Felipe Creek and Salt Creek, where non-native fishes are relatively few (at least currently), the most serious threat may be the abundance of tamarisk/salt cedar (*Tamarix* spp.).

The desert pupfish appears to go through cycles of expansion and contraction in response to natural weather patterns (51 FR 10842–10851; USFWS 1993; Weedman and Young 1997, cited in USFWS 2010). In very wet years, populations can rapidly expand into new habitats (Hendrickson and Varela-Romero 1989, cited in USFWS 2010). In historical times, this scenario would have led to panmixia among populations over a very large geographic area (USFWS 1993).

Population Status and Trends

Global: Critically imperiled (NatureServe 2011)
State: Same as above
Within Plan Area: Same as above

In its 5-year review, USFWS (2010) concluded that threats to the species and their overall level of intensity remain similar to when the species was originally given a recovery priority number of 2C. Priority number 2C is indicative of a high degree of threat, a high potential for recovery, and taxonomic classification as a species.

Threats and Environmental Stressors

USFWS (2010) summarizes the threats to desert pupfish survival. These include threats relating to destruction or curtailment of habitat or range (USFWS Factor A), including loss and degradation of suitable habitat through groundwater pumping or water diversion; contamination from agricultural return flows, as well as other contaminants; and physical changes to water properties involving suitable water quality. There is no new information to suggest that overutilization for commercial, recreational, scientific, or educational purposes (USFWS Factor B) are threats. The effect of disease or predation (USFWS Factor C) is a potential threat to desert pupfish. Currently, the specific effects to individual desert pupfish or populations from disease or parasites are unknown. Predators and competitors of the desert pupfish include tilapia, sailfin mollies, shortfin mollies (*Poecilia mexicana*), mosquitofish, porthole livebearers (*Poeciliposis gracilis*), and several members of the families *Centrarchidae*, *Ictaluridae*, and *Cyprinidae*, as well as melianias (*Melanoides tuberculata* and *Tarebia granifera*), crayfish, Rio Grande leopard frog (*Lithobates berlandieri*), and bullfrog (*Rana catesbeiana*) (51 FR 10842–10851; Black 1980; ICF 2009). Invasive snails (melianias) consume the algal mats that form the pupfish's principal food source (ICF 2009). They also may cause disease. For example, red-rim melania (*Melanoides tuberculatus*) is a host of parasites, including gill trematode. Known fish hosts of the gill trematode include Comanche Springs pupfish (*Cyprinodon elegans*). Juvenile tilapias compete with desert pupfish for many of the same food items (Matsui 1981); and crayfish, frogs and adult tilapia prey on fish and fish eggs (51 FR 10842–10851; ICF 2009; Matsui 1981). Crayfish were thought to be responsible for elimination of the Owens pupfish, *C. radiosus*, from a refuge in Warm Springs near Big Pine, California (Black 1980). Additionally non-native crayfishes are well known to negatively affect water quality and severely reduce, if not eliminate, algae that is favored by pupfish. These and other introduced aquatic species affect pupfish populations through predation, competition, and behavioral interference. Inadequacy of existing regulatory mechanisms (USFWS Factor D) is a potential threat to desert pupfish. Regulatory mechanisms exist in much the same state as at the time of listing, though the application of recent case law may result in reduced consideration of impacts to isolated waters containing desert pupfish (USFWS 2010). Finally, other natural or manmade factors affecting the continued existence of desert pupfish (USFWS Factor E) have been noted as a threat for desert pupfish (USFWS 1993). The only new threat identified is endocrine disruptors noted in the Salton Sea irrigation drains (USFWS 2010).

Conservation and Management Activities

The Coachella Valley MSHCP (CVAG 2007) lists some conservation and management actions that would benefit pupfish:

1. Complete hydrologic studies for the Salt Creek area to determine if the water sources for Salt Creek are adequately protected or if additional water sources may be needed and are available.[1]
2. Ensure persistence of pupfish populations in agricultural drains by managing agricultural drain maintenance and water supply. Monitoring will include surveys for pupfish presence in the agricultural drains along with regular sampling of flow, water depth, and selenium concentrations
3. Control and manage exotic or invasive species in pupfish habitat, if monitoring identifies this as a threat. Control efforts should address nonnative fish, bullfrogs, and other invasive species. The presence and potential impacts of Asian tapeworm, a potential pupfish parasite, shall also be addressed.
    a. Remove tamarisk (salt cedar) where it is affecting the amount of water available to pupfish.
4. Maintain water levels, water quality, and proper functioning condition of ponds, springs, and drains, to the extent these activities are under Plan authority, which will include reevaluating the feasibility of available technologies to reduce selenium concentrations.
5. Restore and enhance degraded habitat as necessary according to monitoring results.
6. Conduct experiments on the timing and mechanics of drain cleaning that would minimize impacts to desert pupfish.
7. Estimate distribution and/or population size of desert pupfish.
8. Survey contaminant levels in the water and in pupfish.

[1] San Felipe Creek and associated wetlands are not within the Coachella Valley MSHCP area, but complete hydrologic studies are needed for this system as well. This will be particularly important given potential impacts of climate change.

USFWS (2010) also lists some general future conservation and management activities:

- A specific standardized genetic protocol should be developed, using work by Echelle et al. (2007), as a template for management of *C. macularius* refuge populations. CDFW is currently working on this issue as part of the Desert Pupfish Refuge Management Plan being developed to provide guidance for the management of pupfish refuges (artificial habitats). Their recommendations include establishing large primary refuge populations, with each one representing the groups of wild *C. macularius*. They also recommend that secondary refuges representing each of the wild source regions be established.
- A recovery plan amendment or revision should be made based on recommendations by Loftis et al. (2009) that delineate a different set of management units in the Salton Sea than is recognized in the existing recovery plan and to reflect the changed taxonomy.
- Conservation at wild sites should be given the highest priority.
- A Safe Harbor Agreement or similar tool for the desert pupfish in California should be pursued.

Additionally, another desired study is determining the tolerance of pupfish eggs to desiccation; this study is currently being planned and is expected to occur soon.

Data Characterization

Loftis et al. (2009) assessed the mitochondrial DNA (mtDNA) results from the 1997 and 1998 surveys by Echelle et al. (2000) and used data from 10 microsatellite DNA loci to describe the genetic structure of the two extant species (*C.* macularius and *C. eremus*). According to Loftis et al., this data showed that there "was evidence (R_{ST}>F_{ST}) that the two extant populations of *C. eremus* have been isolated sufficiently long for mutation to contribute significantly to genetic divergence, whereas divergence among the nine assayed populations of *C. macularius* could be attributed to genetic drift alone." The assessment suggests that based on variability among the mtDNA, there are two populations of *C. eremus* and five groups of populations of *C. macularius* that should be managed as units for conservation genetics management of the two species.

The distribution of the species and principal threats to its continued existence are sufficiently well known to allow coverage of this species in the Desert Renewable Energy Conservation Plan.

Management and Monitoring Considerations

As summarized above, the Coachella Valley MSHCP (CVAG 2007) lists some specific conservation and management actions for the Plan Area that would benefit pupfish. In addition, invasive species management options for the Dos Palmas Area of Critical Environmental Concern have been prepared (ICF 2009) and cover threats to the desert pupfish. Within that document, specific management actions that may be used to eliminate non-native aquatic species or create predator-free environments are evaluated; these include water management that alternately inundates and desiccates habitat, creation of channel habitat, creation of shallow-water habitat, removal and/or burning of emergent aquatic habitat, and invasive aquatic species trapping. As mentioned previously, CDFW is preparing the Desert Pupfish Refuge Management Plan, which will address specific management issues including control of aquatic fauna and flora, genetic protocols for monitoring of pupfish, management recommendations for each refuge, pupfish population monitoring, and other topics. The Desert Pupfish Recovery Plan (USFWS 1993) emphasizes securing extant wild populations of desert pupfish to preserve original genetic material, and creating a second and third tier of populations from these existing wild populations using a genetic exchange protocol that would be created to mimic desert pupfish evolution. Refuge population or new habitat may not be difficult to create as is evidenced by the shallow-water habitat that was constructed near the Alamo River, which was designed to exclude fish, but desert pupfish got into the ponds and flourished (Roberts 2010, cited in USFWS 2010; Saiki et al. 2011). However, habitat may be difficult to maintain in terms of costs. Bureau of

Reclamation spent three million dollars constructing, operating and maintaining this habitat before running out of funding.

Species Modeled Habitat Distribution

This section provides the results of habitat modeling for desert pupfish, using available spatial information and occurrence information, as appropriate. For this reason, the term "modeled suitable habitat" is used in this section to distinguish modeled habitat from the habitat information provided in Habitat Requirements, which may include additional habitat and/or microhabitat factors that are important for species occupation, but for which information is not available for habitat modeling.

There are 8,155 acres of modeled suitable habitat for desert pupfish in the Plan Area. A figure showing the modeled suitable habitat in the Plan Area are included in Appendix C.

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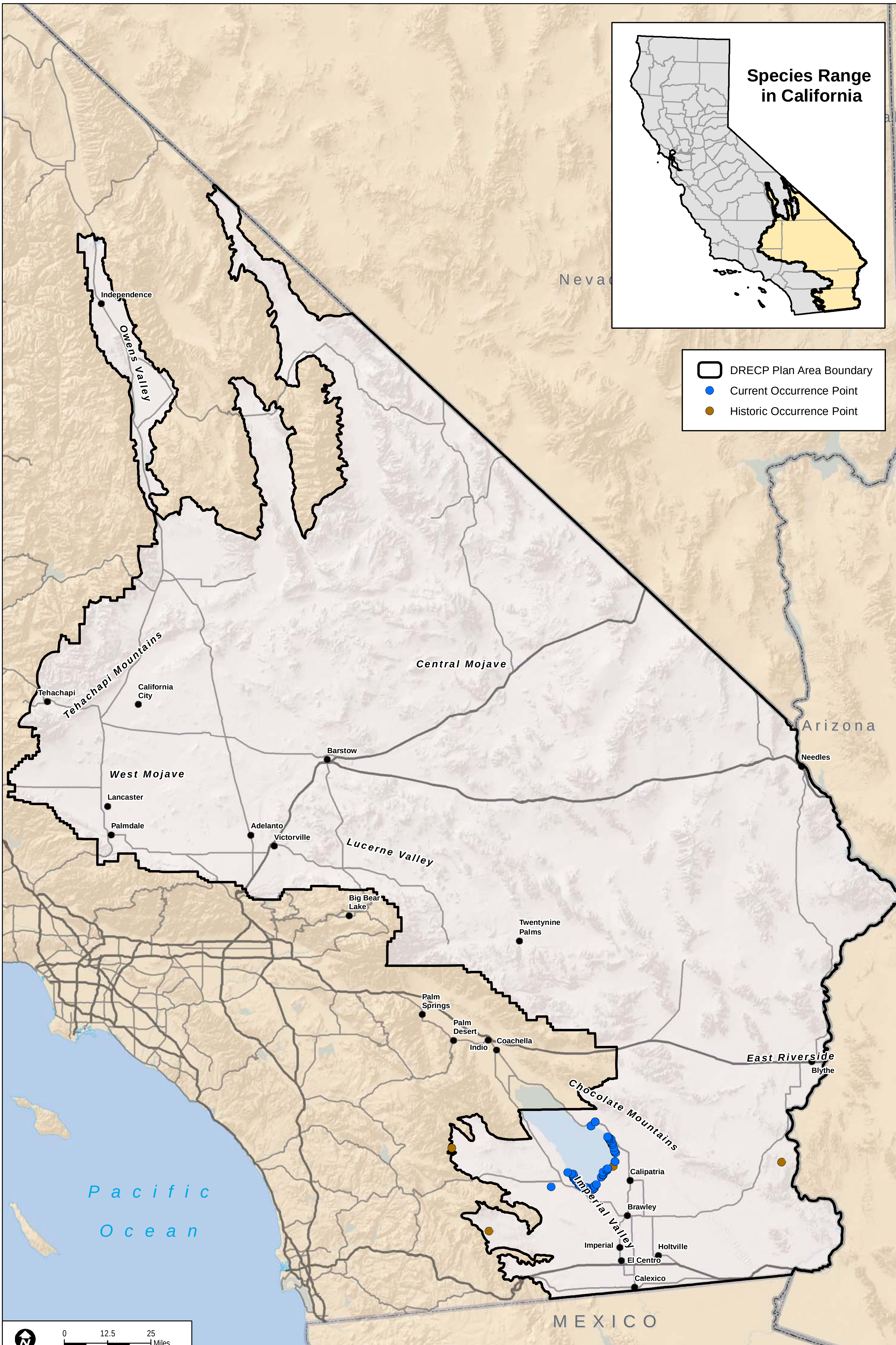

Sources: ESRI (2014); DRECP Species Occurrence Database (2013), CWHR (2008)

FIGURE SP-F01

Desert Pupfish Occurrences in the Plan Area